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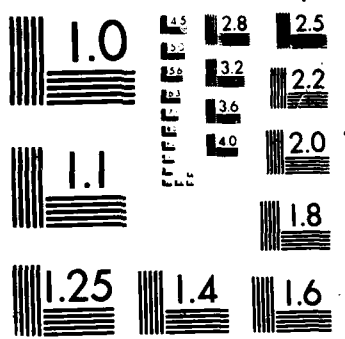
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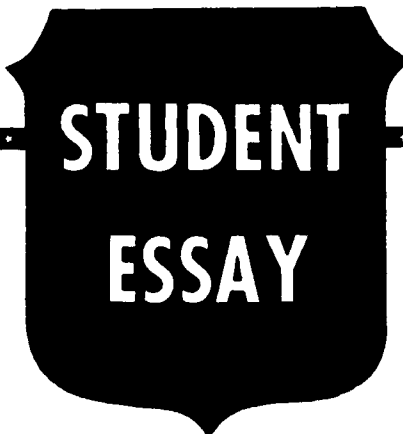
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NUCLEAR WINTER: THE CONTINUING DEBATE

BY

LIEUTENANT COLONEL ANTHONY V. NIDA

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This essay examines the debate over the climatic consequences of global nuclear war as related in the so-called 'Nuclear Winter' hypothesis. The review examines the major components of the theory and traces development of the scientific knowledge leading to a second phase of the controversy two years after the first hypothesis. The conclusions of the essay are that the original nuclear winter findings have been altered by later scientific study and therefore the political conclusions drawn by Carl Sagan in 1983 can no longer be supported by theory or facts. Continued use of the Crutzen-Birks (Ambio, 1982) and TTAPS (Science, December 1983) studies worst case scenarios and war outcome predictions without regard for later evidence from NCAR (Foreign Affairs, Summer 86) represents selective science. Arguing for strategic policy changes based on nuclear winter risks constitutes anti-nuclear rhetoric and not scientific reasoning.

USAWC MILITARY STUDIES PROGRAM PAPER

NUCLEAR WINTER: THE CONTINUING DEBATE

An Individual Essay

by

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Carlisle Barracks, Pennsylvania 17013
23 March 1987

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ABSTRACT

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This essay examines the debate over the climatic consequences of global nuclear war as related in the so-called "Nuclear Winter" hypothesis. The review examines the major components of the theory and traces development of the scientific knowledge leading to a second phase of the controversy two years after the first hypothesis. The conclusions of the essay are that the original nuclear winter findings have been altered by later scientific study and therefore the political conclusions drawn by Carl Sagan in 1983 can no longer be supported by theory or facts. Continued use of the Crutzen-Birks (Ambio, 1982) and TTAPS (Science, December 1983) studies worst case scenarios and war outcome predictions without regard for later evidence from NCAR (Foreign Affairs, Summer 86) represents selective science. Arguing for strategic policy changes based on nuclear winter risks constitutes anti-nuclear rhetoric and not scientific reasoning.

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Nuclear Winter: The Continuing Debate

The Spring of 1983 gave rise to a rekindling of the nuclear arms debate before the American people. Scientific statements describing new scenarios for nuclear war were offered as a vision of a dramatically different future nuclear era. First, from the defense-oriented and scientific groups came a call for high tech strategic defense. President Reagan was convinced that there must be a better means to protect the United States from the horror of nuclear war. In his "Star Wars" speech of March 23, 1983, he offered a proposal "rising above dealing with other nations by threatening their existence" and called on scientists to devise a means of intercepting and destroying the attacking missiles and their warheads in mid-flight in a new Strategic Defense Initiative.¹

The second future scenario was also aimed at altering strategic nuclear thinking. However, rather than offering the promise of security from disaster, it was a portrait of doomsday. Working with climatic computer models scientists postulated that dark smoke from nuclear fires could blot out the sun for extended periods of time following a nuclear war. It was suggested that even though millions might initially survive a nuclear war, they would probably die of famine and disease within the first year.² Thus the nuclear winter theory was born and prompted the the debate between the scientific community and pro-defense researchers which continues today.³ An urgent inquiry was sparked into the scientific validity of a weather catastrophe caused by a massive nuclear attack on cities.

Nuclear weapons have long been considered a threat to the future of mankind.

It is non even impossible to imagine that the effects of an atomic war fought with greatly perfected weapons and pushed by the utmost determination will endanger the survival of man.⁴

Nuclear weapons opponents have sought to eliminate the tools of Armageddon because they saw nuclear war as an impossible option. Scientists in many fields have tried to prove the futility of nuclear weapons and those who employ them. The environmentalists who first interpreted the nuclear winter theory warned that a large scale nuclear war constituted war waged on all peoples on earth, war waged on the global environment itself, and war waged on all members of all foreseeable generations.⁵

Conservative critics have scoffed at the dire predictions and reiterated the long held conviction that the worst horrors of nuclear war are from the direct effects. Analysts and policy makers were disturbed by these emotionally presented studies and were perplexed by the linkage between nuclear winter thresholds and weapons parity.⁶ Like the debates that raged in the scientific community the first decade after Hiroshima, the split between scientists leaves little for the American people to do other than decide which scientist they want to believe. The conflict between Teller and Oppenheimer separated the arms racers from the arms controllers in the early 1950's.⁷ Thirty years later scientists have once again conceived new departures in American policy towards nuclear weapons but no consensus can be derived from the arguments.

It has been three years since the alarm was sounded on nuclear winter. 'In

spite of two or three years of intensive work by many very able scientists, the uncertainties in the predictions remain very real.¹⁶ In the aftermath of the intense and often emotional debate, one is forced to ask, have the proponents of the nuclear winter theory correctly informed the public or has the evidence been corrupted in an attempt to further political and policy objectives? Despite the claims by noted scientists on both sides of the controversy the impact on nuclear policy is not yet discernible. Rethinking nuclear strategy may have to await more conclusive evidence before the issues can be evaluated.

The specter of armageddon cast by the presence of large nuclear arsenals has haunted the public for nearly a generation. Nuclear scenarios have been vividly portrayed in books and movies for so many years that it might seem that they have lost their power to shock their audience. The possibility of nuclear holocaust in the aftermath of future war was warned by the fathers of nuclear warfare even as the first bomb was being constructed. Devastation after war was to be expected. However, the global environmental and social consequences of nuclear war involve such a complex set of interrelated sciences that quantification had until recently not been attempted. Environmental concerns did not develop strong scientific curiosity because the immediate effects of a nuclear burst were always seen as having far greater impact than the delayed effects.

The theory of nuclear winter was first introduced to the general public in the Winter of 1982 within a study called TTAPS. The two year investigation of climate changes after nuclear war drew its name from the initials of its five authors.¹⁷ The best known of these was the popular astronomer Carl Sagan of Cornell University. He has spent considerable energy and devoted his renown

powers of persuasion in the Spring of 1983 toward promoting the climatic catastrophe message and drawing political lessons from the prospect of human annihilation. Speculation about the environmental results of a 'long darkness' were considered by Paul Ehrlich.¹⁰ The term nuclear winter became a house hold word after an abridged version of the TTAPS study appeared in Scientific American in the Summer of 1984.¹¹ The theory was immediately headlines in local papers, on televised debates and made lead articles in a variety of periodicals from psychiatry to foreign affairs throughout 1984.

The fundamental postulate of the nuclear winter theory is that in the event of even a minor nuclear exchange massive amounts of soot and dust from burning targets would block out sunlight plunging much of the world into frigid darkness. Using computer models, the TTAPS scientists analyzed several dozen nuclear war scenarios and estimated the consequences on global atmosphere and climate. The baseline case picked by Sagan and Ehrlich was a 5,000 megaton war in which about 40 percent of the US and Soviet nuclear arsenals would be expended at a combined military, urban and industrial target array. The resulting fires would inject more than 1,200 million tons of dust and soot high into the atmosphere. The amount of sunlight reaching the ground, possibly as little as one percent, could cause inland temperature to drop well below freezing even in summer. Temperatures would plunge to an average minus 13 degrees Fahrenheit and stay at frigid levels for more than three months.

Winter conditions are not the only problems forecast by the TTAPS report. The authors predicted that reduced sunlight would repress or obstruct photosynthesis. The lack of light would cause a rapid extinction of major food crops and other vegetation. Eventually decreased plant life would stop the

conversion of carbon dioxide into oxygen dramatically altering animal life. Darkness would also mean that micro-organisms in the oceans would die causing the starvation of all aquatic life.¹² Thus, all the major food sources in the post war world would be in peril.

The prolonged low temperatures associated with the nuclear winter scenario bring more gloom to the survivors. With post-detonation temperatures tens of degrees below normal the potential for agriculture even in the Southern hemisphere would be futile. Earlier studies have indicated that only a drop of 2 to 3 degrees would entirely eliminate wheat growing in the United States and the Soviet Union.¹³ If the cold lasted for the expected many months, farming of all kinds would cease to exist. Furthermore, in the prolonged darkness supplies of fresh water would freeze to a thickness of several inches hindering basic subsistence. 'It takes no great stretch of the imagination to realize the extreme difficulty of attempting to preserve or rebuild an economy in a radioactive environment, lacking basic food staples, water and oxygen.'¹⁴

We conclude that essentially all terrestrial productivity, including crop production, could be shut down for the first year after a nuclear war, with the obvious implication of human starvation on a massive scale in both hemispheres of Earth....we believe there is a real possibility that no humans would survive in the Northern Hemisphere.¹⁵

At best the authors forecast only small bands of hunters and gatherers would be left in the Southern extremes. The projections of the study, of course, can neither be confirmed or completely refuted since there is no means to conduct an experiment or test the theory. Even though the Turco research team had access to the powerful Cray computer at NASA their representation of worldwide

weather patterns left room for much refinement. There was little doubt among biologists that a sudden change in the climate would not only endanger civilization but humanity itself. However, the uncertainty over how much smoke and dust could be expected in war left room for wide interpretation of the TTAPS predictions.

The sober analysis presented by the TTAPS authors naturally caught the full attention of all sides in the nuclear weapons controversy. Disarmament enthusiasts applauded, political scientists quickly postulated alternative deterrence strategies, and scientists looked for correlations with other effects speculation.

During the continuing debate from 1983 through 1984 the findings presented in the TTAPS study did not prove to be as controversial as some early observers had expected. Although there was general consensus on the risk poised by the hypotheses even the scientists involved explained that a great deal of research remains to be done. In particular the political and strategic conclusions drawn by Sagan were even more coolly received.

The first reaction to the nuclear winter theory came from fellow scientists who were looking at related environmental effects or were familiar with nuclear war scenarios. Environmentalists echoed their technical agreement and many stated their support for the arms race issues and expected alterations in nuclear deterrence and the stability of the Soviet-American confrontation. Moderates from the hard sciences and some social scientists cautiously suggested the possibility of strategic implications should the initial assumptions prove even remotely accurate. As publicity increased, critics joined the debate by faulting the study for simplistic one dimensional

mathematical models. The climatic consequences were drawn from an assumed planet covered by land which did not account for terrain or water interruptions of weather patterns. Even associates at Lawrence Livermore Laboratory thought the study stated a case two or three times as bad as what would actually happen¹⁶ Edward Teller, the so called father of the hydrogen bomb called Sagan's conclusions premature and scolded the authors for not taking into account how much smoke would be washed out of the atmosphere by rains.¹⁷

While the scientific arguments awaited further research, the political consequences of the nuclear winter theory attracted debate participants from many quarters. Experts in nuclear disarmament negotiations condemned Sagan's misuse of weapons stockpile data to give the impression that the capability of the superpowers had increased to provoke nuclear winter.¹⁸ The world's nuclear arsenals have actually decreased in the last decade and technology appears to be leading to smaller more accurate devices.¹⁹ Others charged that the weapons exchange scenario between the superpowers was far too great and was developed simply to exaggerate nuclear winter effects.²⁰

More thoughtful commentators focused on the political consequences and the impact nuclear winter might have on weapons use. An immediate implication of the risk of nuclear winter appeared to be the likelihood that a disarming 'first strike' would become more remote than it is now. Nuclear Winter would cause self deterrence because even if the enemy did not retaliate a first strike would bring destruction to both sides. Sagan called for a global nuclear arsenal reduction to 'below the level at which nuclear winter could conceivably occur,' Implicit in his call for action is the specificity of a threshold at which climatic catastrophe could be triggered.²¹ Thus nuclear

logic dictates a reduction in the worlds arsenal of nuclear weapons below the nuclear winter threshold or what Sagan called the "Doomsday" zone.

Altfield suggests that a major lesson of TTAPS is that any nuclear deterrence strategy based on a counter force attack on cities would increase the likelihood of suicidal climatic effects. Therefore a strategic implication of nuclear winter may be that counter silo is more likely and weapons design and targeting will become even more complex to account for manipulating yields, accuracy and attack timing to control fires.²²

Science advisors George Keyworth and other members of the Reagan Administration cited nuclear winter as further justification for developing the Strategic Defense Initiative first phase systems. This idea was contradicted by many strategic arms consultants who contended that the Soviets were likely to build advanced counter weapons and thereby increase the threat of global holocaust.²³

Another group has have argued that a disturbing outcome of the controversy has been the apathetic reaction by many commentators.²⁴ Attentive observers complained that it would be a serious mistake to believe that nuclear winter does not carry crucial implications for foreign policy. The premise that nuclear winter is just one more horrible outcome of nuclear war is a dangerous foreign policy pitfall. Whether the phenomenon exists or not it must be accounted for in dealing with other nations. Government and civilian panels recommended that high priority be given to serious research to try to answer some of the more elusive questions that the nuclear winter theory raised. Because the debate is confusing and the scientific data so sparse and crude the physicists and biologists seeking to improve knowledge on nuclear winter during

1983 and 1984 focused on four issues: (1) the amount of smoke thrust into the upper atmosphere if large cities were bombed, (2) the size and duration of resultant changes in light, temperature, and rain fall after large fires, (3) the effects on crop production, and the most controversial of all (4) the relationship of these consequences on policy and strategy. Because these questions could not be answered with any clarity from available research many major studies were undertaken after the conferences of 1983. The purpose was to improve the technical knowledge and permit the key conclusion to be drawn: how many megatons would have to be detonated to cause the onset of nuclear winter? Several authors had pondered the implications of the various outcomes of possible research into this question. The more thoughtful had concluded that mid level and low level thresholds would have profound but differing effects on policy and strategy.²⁶

Following the Turco and Ehrlich publications many reports and conference proceedings appeared. The October 1983 conference on 'The World After Nuclear War' held in Washington D.C. was a comprehensive public airing of the past year's reports and included Soviet confirmation of the nuclear winter hypothesis.²⁶ Meanwhile serious inquiries were under way by two major groups. First was an environmental study by SCOPE, the Scientific Committee on Problems of the Environment, an international council of scientists, in session from the Summer 1983 till Fall 1985. Second a National Academy of Sciences investigation funded by the Department of Defense of the climatic effects of nuclear blasts.²⁷

By the time these studies were completed in 1985 news media coverage of the debate had dwindled. The research results stressed similar themes: (1) there

remained great uncertainties in the chain of events leading to the nuclear winter phenomena which may never be completely answered, and (2) there was a possibility of very large climatic effects and their occurrence should not be ignored.²⁸

The debate has been given new dimension in the past year by an article in Foreign Affairs in which National Center for Atmospheric Research (NCAR) researchers reported that new three dimensional computer runs on global weather models showed reduced estimates of temperature reductions that might follow a nuclear exchange. These most recent assessments from the improved global circulation model at NCAR tend to predict smaller (1-30 days) acute effects than TTAPS.²⁹ Although critics of the nuclear winter theory have been quick to judge this new evidence as undermining Sagan's case, the TTAPS authors have come right back with contradictory evidence from recent Los Alamos simulations.³⁰ This divergent scientific opinion is further demonstration of the complexity of the interacting outcomes and the uncertainty of the climate altering mechanisms. Scientists must push the simulations to their extremes and search for new sources of data. 'In particular the estimates of smoke production can not be gleaned from old nuclear test data' or extrapolated from historical accounts of fire storms.³¹

Though there was little fanfare strictly speaking the mathematical probability of total disaster for mankind changed with the three dimensional reports. The latest calculations of high resolution models not only lowered some of the TTAPS worst cases but also indicated the vast uncertainty in many of the assumptions.

No sooner the were new results published then scientists responded because

they thought that policy implications based on the original doubtful concepts needed to be reappraised. As noted earlier, one of the most hotly debated concepts to surface in the nuclear winter debate was the notion that a threshold amount of smoke could trigger catastrophic climate changes. Such a benchmark would have great meaning for deterrence policy, weapons spending, and nuclear weapon employment. Those who believe in threshold called for drastic cuts in the levels of superpower arsenals. If as few as 100 MT could cause nuclear winter then it seemed clear that a ceiling on the world's megatonnage should be the primary disarmament goal. As more climate data was revealed to dispute the nuclear winter hypothesis so too did more criticism of the threshold logic. Thompson and Schneider argued that a threshold was not scientifically persuasive. For instance quick freezes can occur but only over discrete small areas. Threshold has meaning on a local level but it can not be averaged and be expected globally. The notion of threshold can hardly be used to justify a 99-percent reduction in the level of nuclear arsenals.³²

With the arrival of more evidence moderate voices began to be heard as they sought to draw conclusions from the debate. Certainly the early alarmists had at least exaggerated the climatic consequences. By late 1986 after detailed comparison of the NCAR and TTAPS reports scientists were raising grave doubts about the likelihood of an agricultural catastrophe in the northern latitudes, much less south of there. Certainly predictions of the ground being frozen to a meter depth and all fresh water freezing seem overdrawn.³³

Outside of elite scientific and policy making circles the concept of nuclear winter even the revised nuclear autumn has made relatively little impact. It was predicted to be the rallying cry of antinuclear forces.

Certainly it was thought to complicate the public debate over force modernization. However in the late eighties the complexities brought about by strategic nuclear parity, Chernoble and Star Wars have restricted meaningful discussion to the involved scientists and the political technocrats on both sides.

The technical differences on climatic effects after nuclear war narrowed as the nuclear winter debate matured but the rhetoric on implications remained at extremes. The most apparent disagreement between the researchers regards the plausibility of global 'apocalypse'. The assertion by the most recent studies is that 'the question of human extinction can now be relegated to a vanishingly low level of probability.'³⁴ Thus Sagan's claim that 'the stakes are one million times greater for extinction than for the more modest nuclear wars that kill 'only' hundreds of millions of people' is a exaggeration.

A new dimension was added when as one winter producing variable reduced the chance of nuclear winter another estimate was increased to, cause an offsetting effect. In the follow on debate this tendency was criticized. Even more heated was the criticism of the scientific authors attempts to draw policy conclusions from changing evidence. Defense policy analysts believed they overstated their case when they turned to policy considerations. 'Sagan lapses into implicit hemispheric-scale averaging.'³⁵ He also implies a 'trigger' to nuclear winter as if there is a clearly defined point at which enough warheads are delivered to cause irreversible climatic collapse. He even states that this might be caused by a 'pure tactical war in Europe'. This would require the ignition of a huge number of cities which does not appear conceivable in a tactical scenario.

In recent months the reverberation of the Reykjavik summit and apprehension over the forthcoming decisions on the Strategic Defense Initiative have pushed the nuclear winter debate out of the spotlight. As scientific understanding of the nuclear winter mechanisms progresses new study results have tended to pose as many new questions as they have answered. Clearly an analysis of the predicted results of the nuclear winter issue fails to reveal a rejuvenation of the nuclear freeze movement. Technical uncertainty has spilled over from the scientific sector into the public policy forum. Attempts to chart an influential course for the nuclear winter debate failed. Proponents and skeptics of the nuclear winter theory have been frustrated as they attempt to draw policy implications from vague data. The resulting belief seems to be that if the direct effects of a detonation cause total devastation then why become so involved in one more bad consequence of nuclear warfare? Only if the effects of nuclear winter are overwhelming is there import for deterrence, disarmament, and military strategy.

The answer is that apparently no strategic implications exist. In the aftermath of the arguments over the size of nuclear winter subside the lingering result is the thought provoking impact of an even more confused positive and negative pressure on the nuclear deterrence balance. This push pull effect has been caused by the inevitable change in weapons sophistication and their related strategies. The technological premise that modernization produces improved strategy, which provides improved deterrence can not be discerned from recent history and has not be successfully argued in the nuclear winter debate. In trying to quantify or qualify a changing deterrence posture opposing spokesmen contend that the plausible is becoming implausible and vice

versa. Perhaps the acknowledged madness in contemplating nuclear weapons use is fundamental to the maintenance of the perceived deterrence effect.

A consensus has evolved in a few areas of employment and development strategies which can be attributed in some measure to the nuclear winter controversy. Both sides predict that future weapons will be designed to give more flexibility in use. Modernization of nuclear weapons will attempt to achieve the desired target kill with less collateral effects. Nuclear Winter and other target considerations seem to be driving design towards smaller more accurate warheads. Some analysts believe that new employment strategies and weapons characteristics will be demanded. The quantity of particles that fire storms or ground bursts inject into the atmosphere may be reduced or eliminated in various ways: by foregoing attacks on certain types of targets, by using different strike options of yield and height of burst, and by reducing the pace of attack to slow the rate of smoke generation.³⁶ Thus the technologists emphasize the research and development impacts on nuclear winter and do not give much credence to the moral pressures to disarm in the face of horrendous climate changes. If targets in a city must be attacked then several small weapons are most appropriate. It is logical to foresee urban areas receiving less throw weight in a future nuclear attack than major cities received in World War II conventional bombing raids.³⁷ Carried to its limit this technology driven logic winds up at the Jastrow conclusion that nuclear munitions may be dispensed with entirely. Sagan doesn't like this prospect because he sees a mix of new and old nuclear deterrence schemes as more dangerous than either alone because of the instability during transition.

Harwell also stresses the ongoing drive to improve weapon CEP's has the

added effect of reducing the occurrence of nuclear winter and naturally lowering overall inventory of weapons in terms of megatonnage. Concern for nuclear winter whether true or not makes nuclear war more plausible. Altfield sees the argument going both ways in his analysis of the push pull effect of the nuclear winter theory.³⁰

The key variable of cities versus rural targets was a profound one in analysis of the follow on debate. Most agree with the conclusion that counter force wars with deliberate avoidance of cities will result in noncatastrophic climate effects. However, massive counter value attacks on urban areas will probably produce severe effects far beyond the directly effected target area. What effect this damage factor will have beyond target selection is unclear. So long as collateral damage can be mitigated by yield, height of burst, timing, and delivery accuracy it is unlikely that smoke producing potential and seasonal weather will dramatically alter nuclear weapon scenarios.

Regardless of how one may feel about achieving and stabilizing future deterrence strategy or how to make progress in weapons modernization , the impact on future policy by the reduced nuclear winter scenario is not likely to be crucial to decision makers. The revised climatic effects when compared to the other disastrous consequences of nuclear war are hardly overwhelming enough to tip the decision regarding development, deployment or use of nuclear weapons³¹

Nuclear Winter though a interesting new phenomenon is at this time until further study is concluded a diversion from the major nuclear discussion of the day. Strategists have enough to fully occupy their consideration coping with the more predictable results of nuclear war. Other effects bearing on policy

makers are more serious for the future of man. Announcing the death of the Nuclear Winter theory may be premature. Our ability to simulate multidimensional near real time climate with 'super computers' may someday discover additional synergies in the assault on the global ecosystems following a major nuclear exchange. However, in shaping current policy it would be imprudent to guide our survival interests based on tenuous theory, particularly when dealing with perceptions between superpowers.

ENDNOTES

1. Robert Jastrow, How to Make Nuclear Weapons Obsolete, p. 15.
2. Paul J. Crutzen, and John W. Birks, 'The Atmosphere after a Nuclear War: Twilight at Noon.' Ambio, 1982, reprinted in Nuclear War : The Aftermath, ed. by Jeannie Peterson, p. 90.
3. The theory received mass media distribution after the 'World After Nuclear War' Conference held 31 Oct to 1 Nov 1983 in Washington D.C.
4. Edward Teller, 1947 as cited in Wendell K.H. Halm, Nuclear Winter: A Review of the Models, p. vii.
5. Mark A. Harwell, Nuclear Winter: the Human and Environmental Consequences of Nuclear, p. xviii.
6. Halm, p. 1.
7. Gregg Herken, 'American Scientists and U.S. Nuclear Weapons Policy.' Peace and Change, Spring 1985, p. 20.
8. Owen Greene, Ian Percival and Irene Ridge, Nuclear Winter: the Evidence and the Risks, p. 5.
9. R.P. Turco, O.B. Toon, T.P. Ackerman, J.P. Pollack, and C. Sagan. 'Nuclear Winter: Global Consequences of Multiple Nuclear Explosions.' Science, 23 December 1983, p. 1283.
10. Crutzen, p. 73.
11. Richard P. Turco, et al. 'The Climatic Effects of Nuclear War,' Scientific American, August 1984, pp. 33-43.
12. Carl Sagan, 'Nuclear War and Climatic Catastrophe: Some Policy Implications.' Foreign Affairs, Winter 1983/84, pp. 260-270.
13. J.J. Gertler, Some Policy Implications of Nuclear Winter, p. 3.
14. Gertler, p. 3.
15. Harwell, p. xvii.
16. 'A Cold Dark Apocalypse,' Time, 14 November 1983, p. 43.
17. Michael F. Altfield and Stephen J. Cimbala, 'Targeting for Nuclear Winter: A Speculative Essay,' Parameters, 3 August 1985, p. 10.
18. Edward N. Luttwak, 'Comment and Correspondence: Nuclear Winter,' Foreign Affairs, Spring 1984, p. 997.

19. Lynn R. Sykes and Dan M. Davis, 'The Yields of Soviet Strategic Weapons,' Scientific American, Vol. 256, January 1987, pp. 29-37. New research has shown a possible exaggeration of yields in that a rough parity in terms of megatonnage exist between the two super powers.
20. Gertler, p. 1.
21. Sagan, p. 292.
22. Altfield, p. 9.
23. 'Debate Over a Frozen Planet,' Time, 24 December 1984, p. 57.
24. Gertler, p. 1.
25. Dennis M. Drew, LTC, Nuclear Winter and National Security: Implications for Future Policy, p. 20.
26. Dr. Leon Goure, Soviet Exploitation of the Nuclear Winter Hypothesis, p. 63. Although highly publicized later analysis has shown that the work by the Soviet mathematicians, Alexsandrov and Golitsyn was a shoddy pretense of independent work. The Soviets had massaged the U.S. studies and presented their 'rehash' of Sagan's and Ehrlich's works for propaganda purposes.
27. Catherine Caufield, 'Dark and Cold: The Aftermath of Nuclear War.' New Scientist, 15 September 1983, p. 753.
28. Starley L. Thompson, and Stephen H. Schneider, 'Nuclear Winter Reappraised.' Foreign Affairs, Summer 1986, p. 989.
29. George F. Carrier, et al., The Effects on the Atmosphere of a Major Nuclear Exchange.
30. Robert C. Malone, et al., Nuclear Winter: Three Dimensional Simulations Including Interactive Transport, Scavenging and Solar Heating of Smoke, pp. 27-29.
31. Thompson, p. 984.
32. Starley L. Thompson, and Stephen H. Schneider, 'Comment and Correspondence: The Nuclear Winter Debate,' Foreign Affairs, Fall 1986, p. 172.
33. George W. Rathjens and Ronald H. Siegel, 'Comment and Correspondence: The Nuclear Winter Debate,' foreign Affairs 65(Fall 1986):169-71.
34. Thompson, p 173.
35. Thompson p. 175.
36. Drew, p 28.

37. Altfield, p. 13.

38. Altfield, p 8-9.

39. Rathjens, p 170.

BOOKS

- Alexsandrov, V. V., and Stenchikov, G. L. On the Modelling of the Climatic Consequences of the Nuclear War. Moscow: USSR Academy of Sciences, Computing Centre, 1983. (U767 A43)
- Ball, Desmond, and Richelson, Jeffery, ed. Strategic Nuclear Targeting. Ithaca: Cornell, 1986. (U263 S76 1986)
- Carrier, George F., et al. The Effects on the Atmosphere of a Major Nuclear Exchange. Washington: National Academy, 1985. (U263 E4 1985)
- Conference on the Long-Term Worldwide Consequences of Nuclear War, Washington D.C., 1983 The Cold and the Dark: The World after Nuclear War, by Paul Ehrlich, et al. New York: Norton, 1984. (QH545 N83 C66 1983)
- Caldicott, Helen. Missile Envy: The Arms Race and Nuclear War. New York: Bantam, 1986. (U264 C34 1986)
- Drew, Dennis M., LTC. Nuclear Winter and National Security: Implications for Future Policy. Maxwell Air Force Base: Air University, 1986. (U263 N845 1986)
- Feldbaum, Carl B, et al. Implications of the Nuclear Winter Thesis. Washington: Defense Nuclear Agency, 24 June 1985. (DNA-TR-85-29) (U263 I47 1985)
- Gertler, J.J. Some Policy Implications of Nuclear Winter. Washington: The Rand Corporation, 1985. (U263 G47 1985)
- Goure, Dr. Leon. Soviet Exploitation of the Nuclear Winter Hypothesis. Washington: Defense Nuclear Agency, 1985. (DNA-TR-84-373) (U263 G67 1985)
- Greene, Owen, Percival, Ian and Ridge, Irene. Nuclear Winter: the Evidence and the Risks. Cambridge: Polity Press, 1985. (U263 G73 1985)
- Grinspoon, Lester, ed., The Long Darkness: Psychological and Moral Perspectives on Nuclear Winter. New Haven: Yale, 1986. (U263 L664 1986)
- Harwell, Mark A. Nuclear Winter: the Human and Environmental Consequences of Nuclear War. New York: Springer, 1984. (U263 h37 1984)
- Halm, Wendell. Nuclear Winter: A Review of the Models. Santa Monica: Rand Corporation, 1985. (U263 H34 1985)
- Irwin, Michael H. K. Can We Survive Nuclear War? Public Affairs Pamphlet No. 625. New York: Public Affairs Committee, 1984. Pp. 24-26. (H35 p8 no. 625)
- Jastrow, Robert. How to Make Nuclear Weapons Obsolete. Boston: Little, 1985. (U263 J377 1985)

- Malone, Robert C., Auer, Lawrence H., Glalzman, Gary A., Wood, Michael C., Toon, Owen B., Nuclear Winter: Three Dimensional Simulations Including Interactive Transport, Scavenging and Solar Heating of Smoke, Los Alamos: Los Alamos National Laboratory, May 1985. (LA-UR-85-1890) (U263 N8 1985)
- Royal Swedish Academy of Sciences, Nuclear War: The Aftermath, Oxford: Pergamon, 1983. (UF767 N777 1982)
- Schell, Jonathan. The Abolition. New York: Knopf, 1984. Pp. 16-19. (JX1974.7 S2194 1984)
- US National Research Council. Committee on the Atmospheric Effects of Nuclear Explosions. The Effects on the Atmosphere of a Major Nuclear Exchange. Washington: National Academy Press, 1985. (U263 E4 1985)
- Weinberger, Casper W. The Potential Effects of Nuclear War on the Climate: A Report to the United States Congress. Washington: US Department of Defense, March 1985. (U263 W4)

PERIODICALS

- 'A Cold Dark Apocalypse.' Time, Vol. 122, 14 November 1983, p. 43.
- Altfield, Michael F. and Cimbala, Stephen J., 'Targeting for Nuclear Winter: A Speculative Essay,' Parameters, Vol 15, Autumn 1985, pp. 8-15.
- Baum, Ruby M. 'Climate Changes Focus of Research on Effects of Nuclear War.' Chemical and Engineering News, Vol. 61, 19 December 1983, pp. 16-17. (Reprint File)
- Bayles, Fred. 'Scientists Debate What Lies after 'The Day After': Would 'Nuclear Winter' Endanger Life Itself?' Patriot News (Harrisburg, PA), 18 November 1984, p. A12.
- Broad, William J. 'U.S. Weighs Risk That Atom War Could Bring Fatal Nuclear Winter.' New York Times, 5 August 1984, pp. 1, 40.
- Buteux, Paul. 'Nuclear Winter.' International Perspectives, September-October 1984, pp. 27-29.
- Caufield, Catherine. 'Dark and Cold: The Aftermath of Nuclear War.' New Scientist, Vol. 99, 15 September 1983, p. 753. (Reprint File)
- Cohen, Sam. 'Nuclear Winter vs. Nuclear Reality.' Colorado Springs Gazette-Telegraph, 15 July 1984, p. 25. (Reprint File)
- 'Commentary: Environmental Consequences of Nuclear War, The State of the Debate.' Environment, 28 October 1986, p. 2.

- Crutzen, Paul J. and Birks, John W. 'The Atmosphere after a Nuclear War: Twilight at Noon.' Ambio, Vol 11, 1982, reprinted in J. Peterson (ed.) Nuclear War : The Aftermath, (Special Ambio Publication) Oxford: Pergamon, 1983, pp. 73-96.
- 'Debate over a Frozen Planet.' Time, Vol. 124, 24 December 1984, pp. 56-57.
- Ehrlich, Paul R., et al. 'Long-Term Biological Consequences of Nuclear War.' Science, Vol. 222, 23 December 1983, pp. 1293-1300.
- Ehrlich, Paul R. 'North America After the War.' Natural History, Vol. 93, March 1985, pp. 4,6,8. (Reprint File)
- Herken, Gregg, 'American Scientists and U.S. Nuclear Weapons Policy.' Peace and Change, Vol 11, Spring 1985, pp. 19-27.
- Hilts, Philip J. ''Nuclear Winter' Castastrophe Confirmed by Soviet Scientists.' Washington Post, 2 November 1983, p. A8.
- Hilts, Philip J. 'Scientists Say Nuclear War Could Cause Climatic Disaster.' Washington Post, 1 November 1983, pp. A1, A6.
- Hilts, Philip J. 'U.S. Begins Study of Possible Climatic Disaster in Nuclear War.' Washington Post, 29 May 1984, p. A6.
- Hunter, Lloyd P., and Turco, Richard P. 'More on Nuclear Winter.' Letters to the editor. Physics Today, Vol. 37, June 1984, pp. 95-96. (Reprint File)
- Lees, David. 'A Closer Look at the Bomb.' Macleans, Vol. 97, 20 August 1984, p. 48.
- Levi, B.G. 'Atmospheric Calculations Suggest a Nuclear Winter.' Physics Today, Vol. 37, February 1984, pp. 17-20. (Reprint File)
- London, Herbert I. 'The New Prophets of Doom.' USA Today, Vol. 113, September 1984, pp. 64-65.
- Luttwak, Edward N. 'Comment and Correspondence: Nuclear Winter.' Foreign Affairs, Vol. 62, Spring 1984, p. 997.
- Maddox, John. 'Nuclear Winter Not Yet Established.' Nature, Vol. 308, 1 March 1984, p. 11. (Reprint File)
- 'Military Experts Accept 'Nuclear Winter' Scenario.' Washington Post, 12 July 1984, p. A32.
- 'Pentagon Aides Agree on a 'Nuclear Winter'.' New York Times, 13 July 1984, p. A13.
- Physics Today, Vol. 35, October 1982, pp. 17-20. (Reprint File)
- Rathjens, George W., and Siegel, Ronald H. 'Comment and Correspondence: The

- Nuclear Winter Debate.' Foreign Affairs, Vol. 65, Fall 1986, pp. 169-171.
- Sagan, Carl. 'Nuclear War and Climatic Catastrophe: Some Policy Implications.' Foreign Affairs, Vol. 62, Winter 1983/84, pp. 257-292.
- Sykes, Lynn R., and Davis, Dan M. 'The Yields of Soviet Strategic Weapons.' Scientific American, Vol. 256, January 1987, pp. 29-37.
- 'The Nuclear Winter Threat.' Discover, Vol. 5, January 1984, pp. 10-11.
(Reprint File)
- Thompson, Starley L., and Schneider, Stephen H. 'Comment and Correspondence: The Nuclear Winter Debate.' Foreign Affairs, Vol. 65, Fall 1986, pp. 171-178.
- Thompson, Starley L., and Schneider, Stephen H. 'Nuclear Winter Reappraised.' Foreign Affairs, Vol. 64, Summer 1986, pp. 982-1005.
- Turco, R.P., Toon, O.B., Ackerman, T.P., Pollack, J.P., and Sagan, C., 'The Climatic Effects of Nuclear War.' Scientific American, Vol 25, August 1984, pp. 33-43.
- Turco, R.P., Toon, O.B., Ackerman, T.P., Pollack, J.P., and Sagan, C., 'Nuclear Winter: Global Consequences of Multiple Nuclear Explosions.' Science, Vol 222, 23 December 1983, pp. 1283-1292.

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